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(54) **ELECTROHYDRAULIC VALVE CALIBRATION SYSTEM AND METHOD**

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F16K 37/00	(2006.01)
F16K 31/06	(2006.01)

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CPC ***F16K 31/02*** (2013.01); ***F15B 1/00*** (2013.01); ***F16K 31/0613*** (2013.01); ***F16K 37/0091*** (2013.01)

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USPC 137/565.16; 700/282; 91/459, 469; 73/1.72

See application file for complete search history.

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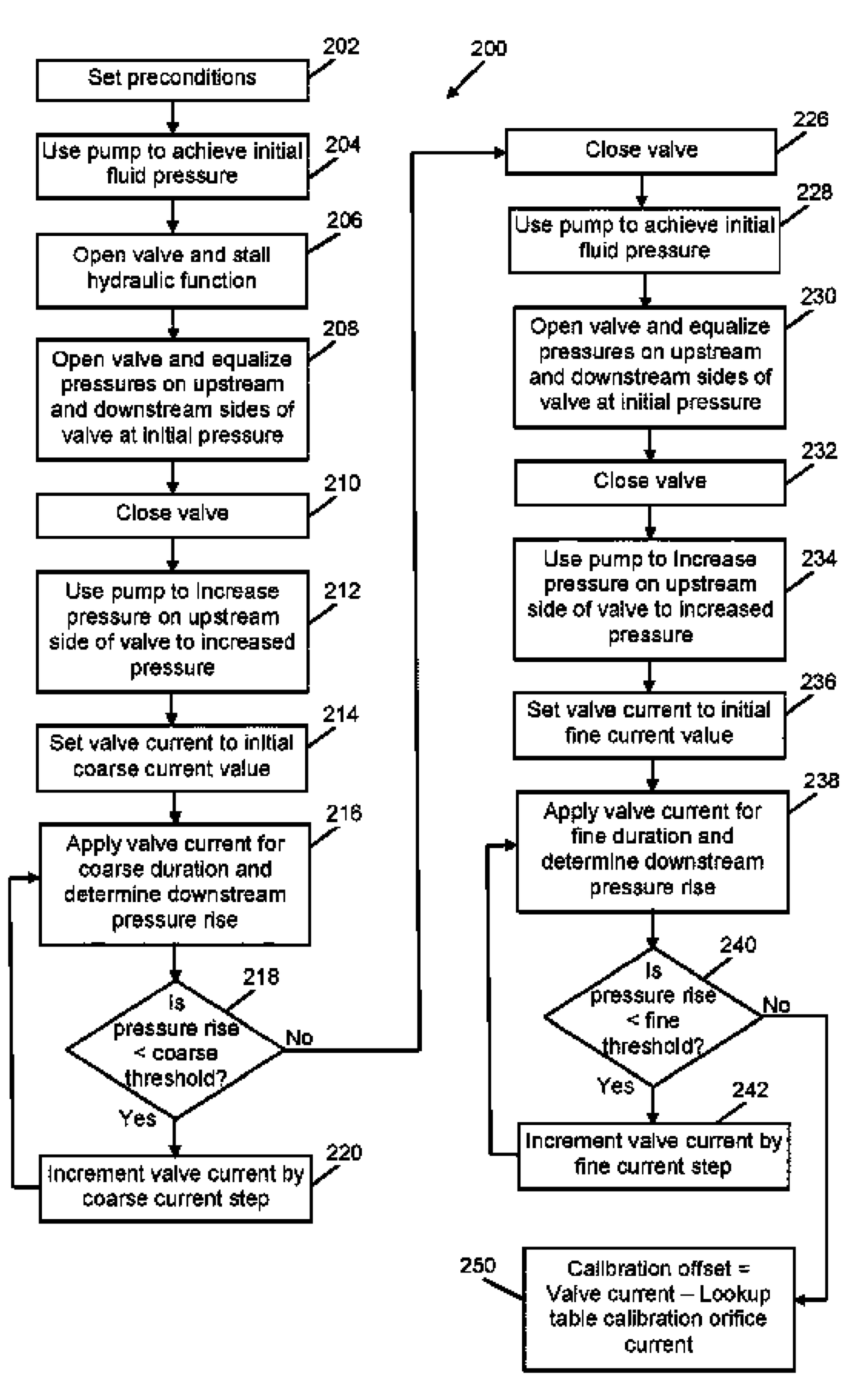
(57) **ABSTRACT**

A valve calibration system and method is disclosed for an electrohydraulic valve having upstream and downstream sides. A valve current controls the valve orifice size connecting the upstream and downstream sides. The calibration method includes opening the valve, stalling the system to prevent volume changes, and closing the valve with substantially equalized upstream and downstream pressures; then increasing upstream pressure, and finding a calibration current that provides a calibration orifice size through the valve by monitoring downstream pressure. Finding a calibration current can include stepping through valve control currents, sensing downstream pressures, and calculating step orifice sizes until the calculated step orifice size is greater than or equal to the calibration orifice size. Finding a calibration current can include performing a coarse calibration followed by a finer calibration. An offset can be calculated for a valve characteristic relating valve control current to valve orifice size.

20 Claims, 2 Drawing Sheets



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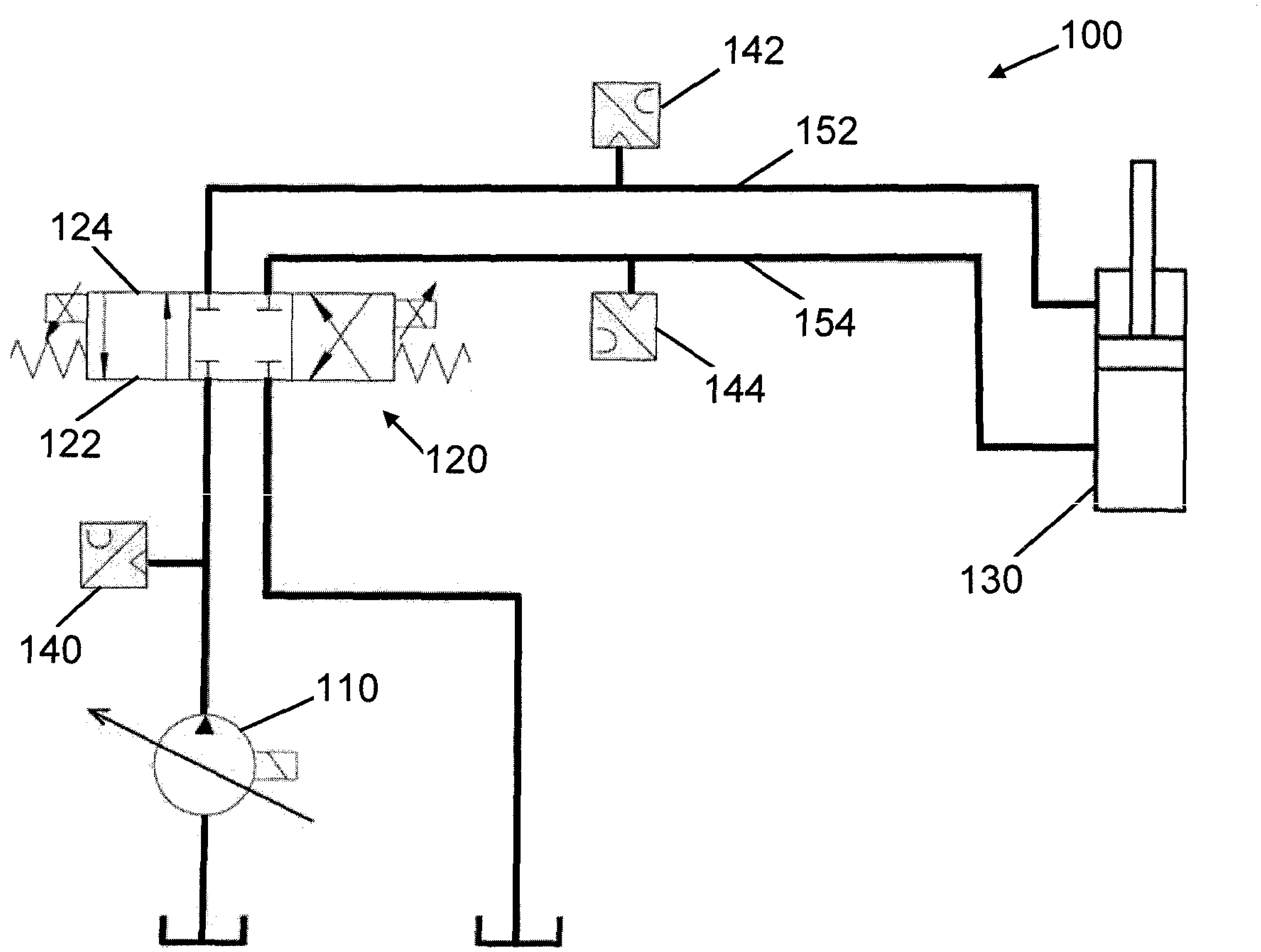

Figure 1

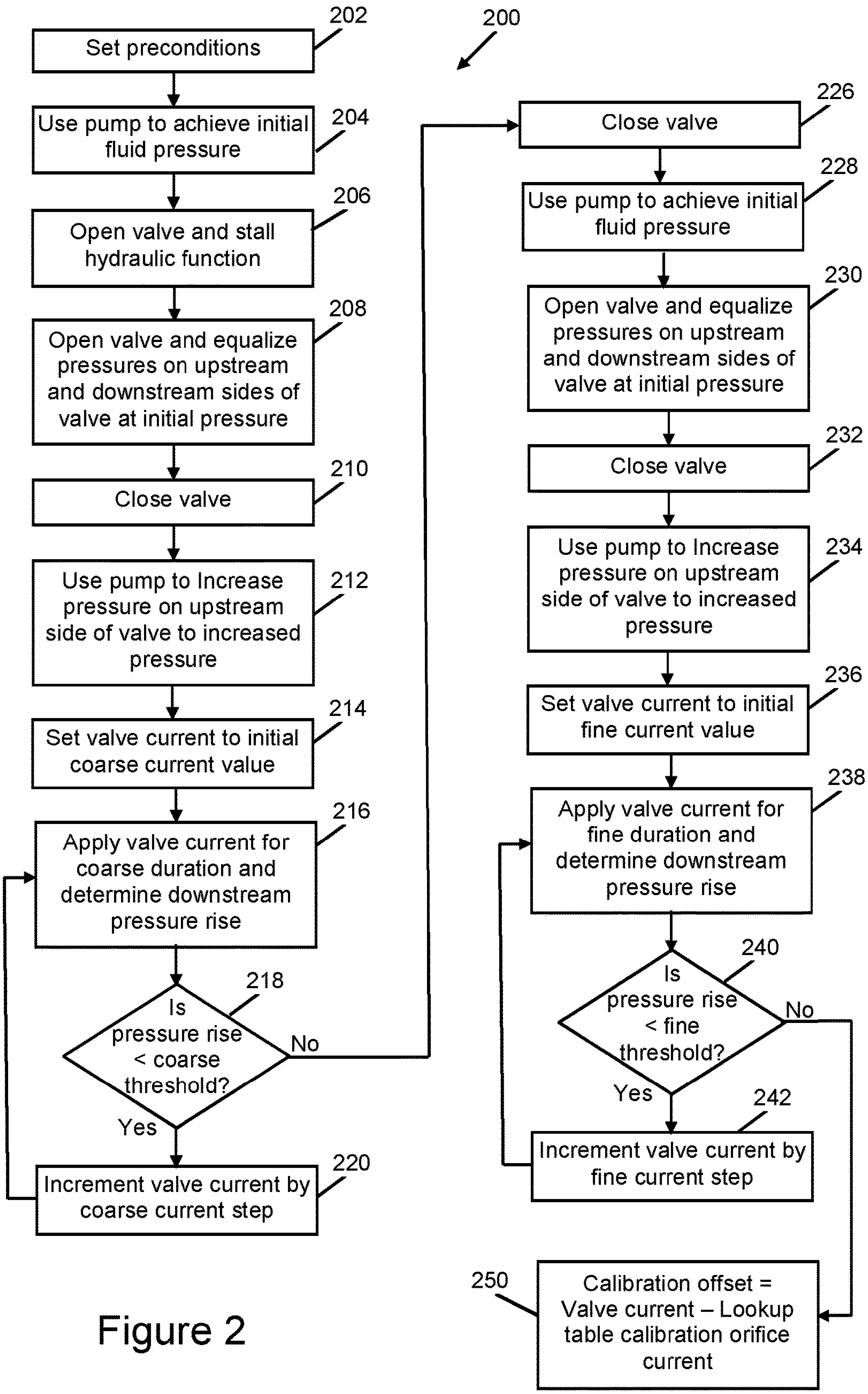
200
Set preconditions
202
Use pump to achieve initial fluid pressure
204
Open valve and stall hydraulic function
206
Open valve and equalize pressures on upstream and downstream sides of valve at initial pressure
208
Close valve
210
Use pump to Increase pressure on upstream side of valve to increased pressure
212
Set valve current to initial coarse current value
214
Apply valve current for coarse duration and determine downstream pressure rise
216
Is pressure rise < coarse threshold?
218
No
Yes
Increment valve current by coarse current step
220
Close valve
226
Use pump to achieve initial fluid pressure
228
Open valve and equalize pressures on upstream and downstream sides of valve at initial pressure
230
Close valve
232
Use pump to Increase pressure on upstream side of valve to increased pressure
234
Set valve current to initial fine current value
236
Apply valve current for fine duration and determine downstream pressure rise
238
Is pressure rise < fine threshold?
240
No
Yes
Increment valve current by fine current step
242
Calibration offset = Valve current – Lookup table calibration orifice current
250

Figure 2

ELECTROHYDRAULIC VALVE CALIBRATION SYSTEM AND METHOD

FIELD OF THE DISCLOSURE

The present disclosure relates to the calibration of an electrohydraulic valve, and more particularly to calibration of a valve control current controlling an orifice size through an electrohydraulic valve.

BACKGROUND

In an electrohydraulic (EH) system, an electronically controlled valve is typically designed to have a certain current control characteristic. In other words, the current that is driven to the valve control solenoid will either directly or indirectly displace the valve spool. The spool may require a certain minimum amount of displacement before it enters its metering range, which is the range at which fluid starts to flow across the valve. This spool displacement, and the current required to get this displacement, are often designed to occur at a specific point. However, due to manufacturing tolerances, the imprecision of this "start of flow" or "cracking" point may not be adequate for a particular application.

The area of the opening or orifice allowing the flow of fluid through an electrohydraulic valve is controlled by a valve current. An electrohydraulic valve has a current dependent metering range between a cracking current and a saturation current. The cracking current is the valve current value at which the valve orifice is very slightly open allowing a very small flow of fluid through the valve. The saturation current is the valve current value at which the valve orifice is fully open allowing the maximum flow of fluid through the valve. The valve current control characteristic relating valve current to valve orifice size over the metering range is usually well characterized. A supplier valve current control characteristic is typically provided with a valve by the supplier. The supplier valve current control characteristic is usually accurate in shape but often needs to be offset to account for variances between valves, for example manufacturing variations, machining tolerances, etc., and impacts of valve environments.

A valve calibration routine can be implemented to estimate a start of flow point or cracking point to use as an offset for the supplier valve current control characteristic. One method involves a system with a load sensing hydraulic pump where the valve start of flow point can be determined by observing the pump output pressure while the hydraulic function downstream of the valve is in a stalled condition. In this scenario, the cracking of the valve induces a load sense signal that drives the pump up to pressure. However, this method cannot be used for calibration in an electrohydraulic system using a pump with an electronically controlled displacement. The cracking point and cracking current to produce this "start of flow" point is also very sensitive to manufacturing variations, machining tolerances, fluid temperatures, flow forces and various other factors.

It would be desirable to have a valve calibration system and method to calibrate an electrohydraulic valve that has greater stability and repeatability, and that can also be used for pumps with electronically controlled displacement.

SUMMARY

A calibration method is disclosed for an electrohydraulic valve in an electrohydraulic system driven by a pump, where the electrohydraulic valve has an upstream side between the pump and the electrohydraulic valve and a downstream side on the opposite side of the electrohydraulic valve from the pump. A valve control current controls an orifice size through the electrohydraulic valve connecting the upstream side with the downstream side. The calibration method includes opening the electrohydraulic valve, stalling the electrohydraulic system to prevent volume changes in the electrohydraulic system during calibration, closing the electrohydraulic valve with the upstream and downstream sides of the electrohydraulic valve substantially equalized at an equalization pressure, increasing pressure on the upstream side of the electrohydraulic valve to an increased pressure using the pump, and finding a calibration valve control current that provides a calibration orifice size through the electrohydraulic valve by monitoring pressure on the downstream side of the electrohydraulic valve. The increased pressure on the upstream side of the electrohydraulic valve after the valve is closed is greater than the equalization pressure on the downstream side of the valve. The pump can have an electronically controlled displacement.

Finding a calibration valve control current can include initializing a step current to an initial current value, setting the valve control current for the electrohydraulic valve to the step current for a step duration, sensing pressure on the downstream side of the electrohydraulic valve after setting the valve control current to the step current for the step duration, and calculating a step orifice size through the electrohydraulic valve based on the sensed pressure on the downstream side of the electro hydraulic valve. If the calculated step orifice size is less than the calibration orifice size, then increasing the step current by a current increment and repeating the setting, sensing and calculating steps for the increased step current. If the calculated step orifice size is greater than or equal to the calibration orifice size, then using the step current as the calibration valve control current. The electrohydraulic valve is closed when the valve control current equals the initial current value. Calculating a step orifice size based on the sensed pressure on the downstream side of the electrohydraulic valve can include determining a flow rate through the electrohydraulic valve based on the difference in sensed pressure on the downstream side of the electrohydraulic valve before and after setting the valve control current to the step current for the step duration, and determining the step orifice size of the electrohydraulic valve for the step current using the determined flow rate through the electrohydraulic valve and the compressibility of the fluid in the electrohydraulic system.

The electrohydraulic valve can have a valve current control characteristic relating the valve control current to the orifice size through the electrohydraulic valve. The calibration method can also include calculating a table offset for the valve current control characteristic based on the calibration valve control current that provides the calibration orifice size. Calculating a table offset for the valve current control characteristic can include using the valve current control characteristic to determine a table current entry for the valve control current that provides the calibration orifice size, and computing the table offset as the difference between the table current entry and the calibration valve control current. The calibration orifice size can be selected to reduce manufacturing tolerance impacts on the calibration method.

The flow rate through the electrohydraulic valve can be greater than zero for at least one step current before increasing the step current to the calibration valve control current. The calibration method can also include selecting the initial current value and the step duration to maintain a pressure difference between the upstream side and the downstream

side of the electrohydraulic valve when the calculated step orifice size is greater than or equal to the calibration orifice size.

Finding a calibration valve control current can include performing a coarse calibration and then performing a finer calibration. Performing a coarse calibration can include starting at an initial coarse current value and using a coarse current increment to find a coarse control current estimate. Performing a finer calibration can include starting at an initial finer current value and using a finer current increment to find the control current estimate. The initial finer current value can be selected based on the coarse control current estimate, and the finer current increment can be less than the coarse current increment. The electrohydraulic valve can be closed when the valve control current equals the initial coarse current value.

Performing a coarse calibration can further include initializing the valve control current to the initial coarse current value, applying the valve control current to the electrohydraulic valve for a coarse step duration, sensing pressure on the downstream side of the electrohydraulic valve after applying the valve control current for the coarse step duration, and calculating a step orifice size through the electrohydraulic valve based on the sensed pressure on the downstream side of the electrohydraulic valve. If the calculated step orifice size is less than the calibration orifice size, then the coarse calibration can also include increasing the valve control current by the coarse current increment and repeating the applying, sensing and calculating steps of the coarse calibration for the increased valve control current. If the calculated step orifice size is greater than or equal to the calibration orifice size, then the coarse calibration can also include setting the coarse control current estimate to the valve control current.

Performing a finer calibration can further include initializing the valve control current to the coarse control current estimate minus a current offset, applying the valve control current to the electrohydraulic valve for a finer step duration, sensing pressure on the downstream side of the electrohydraulic valve after applying the valve control current for the finer step duration, and calculating the step orifice size through the electrohydraulic valve based on the sensed pressure on the downstream side of the electrohydraulic valve. If the calculated step orifice size is less than the calibration orifice size, then the finer calibration can also include increasing the valve control current by the finer current increment and repeating the applying, sensing and calculating steps of the finer calibration for the increased valve control current. If the calculated step orifice size is greater than or equal to the calibration orifice size, then the finer calibration can also include setting the control current estimate to the valve control current.

The coarse current increment can be at least double the finer current increment. After performing the coarse current calibration and before performing the finer current calibration, the calibration method can further include equalizing pressures on the upstream and downstream sides of the electrohydraulic valve at the equalization pressure, closing the valve with the upstream and downstream pressures equalized at the equalization pressure, and increasing pressure on the upstream side of the electrohydraulic valve to the increased pressure using the pump.

An electrohydraulic valve calibration system is disclosed that includes an electrohydraulic valve, a pump, a hydraulic actuator, upstream and downstream pressure sensors and a controller. The electrohydraulic valve has a variable size orifice. The orifice size through the electrohydraulic valve is controlled by a valve control current. Fluid flows through the variable size orifice between an upstream side and a downstream side of the electrohydraulic valve. The pump is on the upstream side of the electrohydraulic valve. The hydraulic actuator is on the downstream side of the electrohydraulic valve. The pump pumps fluid from the upstream side through the electrohydraulic valve to the downstream side. The upstream pressure sensor senses an upstream fluid pressure on the upstream side of the electrohydraulic valve. The downstream pressure sensor senses a downstream fluid pressure on the downstream side of the electrohydraulic valve. The controller opens the electrohydraulic valve, stalls the hydraulic actuator and then closes the electrohydraulic valve with the upstream and downstream fluid pressures at an equalization pressure. The controller then activates the pump to increase the upstream fluid pressure to an increased pressure, and finds a calibration valve control current that provides a calibration orifice size through the electrohydraulic valve by monitoring the downstream fluid pressure. The pump can have an electronically controlled displacement.

The controller can sequentially step through a series of increasing valve control currents until the calibration valve control current is determined. At each step in the series of increasing valve control currents, the controller can sense the downstream fluid pressure and calculate a step orifice size through the electrohydraulic valve based on the sensed downstream pressure. The controller can determine the calibration valve control current based on the valve control current of the step where the calculated step orifice size is greater than or equal to the calibration orifice size. The controller can calculate a flow rate through the electrohydraulic valve based on a change in the sensed downstream fluid pressure before and after each step in the series of increasing valve control currents, and calculate the step orifice size using the calculated flow rate through the electrohydraulic valve and a compressibility of the fluid. A valve current control characteristic relating the valve control current to the orifice size through the electrohydraulic valve can also be used. The controller can calculate a current offset for the valve current control characteristic based on the calibration valve control current and the calibration orifice size. The current offset can be calculated as the difference between a table current entry in the valve current control characteristic for the valve control current that provides the calibration orifice size and the calibration valve control current.

The controller can start at an initial coarse valve control current and sequentially step through a series of increasing valve control currents at a coarse current increment until a coarse valve control current estimate is determined, and then start at an initial finer valve control current and sequentially step through a series of increasing valve control currents at a finer current increment until the calibration valve control current estimate is determined. The finer current increment can be less than the coarse current increment, and the initial finer valve control current can be determined based on the coarse valve control current estimate. At each step in the series of increasing valve control currents, the controller can sense the downstream fluid pressure and calculate a step orifice size through the electrohydraulic valve based on the sensed downstream pressure, and the controller can stop the sequential steps when the calculated step orifice size is greater than or equal to the calibration orifice size.

The above and other features will become apparent from the following description and the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description of the drawing refers to the accompanying figures in which:

FIG. **1** illustrates an exemplary hydraulic circuit including a pump, a valve, a hydraulic actuator and pressure sensors; and

FIG. **2** illustrates an exemplary electrohydraulic valve calibration method.

DETAILED DESCRIPTION

The area of the opening or orifice allowing fluid flow through an electrohydraulic valve is controlled by a valve current. An electrohydraulic valve has a current dependent metering range between a cracking current, which slightly opens the valve orifice, and a saturation current, which fully opens the valve orifice. The valve current control characteristic relating valve current to valve orifice size over the metering range is generally well characterized. Even though the supplier valve current control characteristic is usually accurate in shape, it often needs to be offset to account for variances between valves, for example manufacturing variations, machining tolerances, etc.

The valve calibration system and method uses certain conditions within the hydraulic system, for example, the fluid pressure on both the upstream and downstream sides of the valve being calibrated, and the fluid temperature. The valve calibration system and method also utilizes the relationship between pressure and volume when fluid is compressed in a stalled circuit, and the relationship between pressure and flow over a known hydraulic orifice. The very small orifice achieved by the cracking current is very sensitive to manufacturing variations, machining tolerances, fluid temperatures, flow forces and various other factors. A somewhat greater valve orifice size and flow value for calibration can be used for greater stability, consistency and repeatability

FIG. **1** illustrates an exemplary hydraulic circuit **100** including a pump **110**, a valve **120** and a hydraulic actuator **130**. The valve **120** has an upstream side **122** closest to the pump **110** and a downstream side **124** closest to the hydraulic actuator **130**. The pump **110** pumps fluid to the upstream side **122** of the valve **120** and, when the valve **120** is open the fluid flows through the valve **120** to the hydraulic actuator **130**. A return path is also shown from the hydraulic actuator **130** through the valve **120** to a sink. The hydraulic circuit **100** also includes three pressure sensors **140**, **142**, **144**. The first pressure sensor **140** monitors the fluid pressure on the upstream side **122** of the valve **120**. The second pressure sensor **142** monitors the fluid pressure on the downstream side **124** of the valve **120** in downstream fluid path **152** that can be pressurized to retract the hydraulic actuator **130**. The third pressure sensor **144** monitors the fluid pressure on the downstream side **124** of the valve **120** in downstream fluid path **154** that can be pressurized to extend the hydraulic actuator **130** on the downstream side **124** of the valve **120**.

The valve **120** can be calibrated independently for the two fluid paths **152**, **154** that it controls. The appropriate pressure sensor **142**, **144** corresponding to the fluid path **152**, **154** that is being calibrated is used to monitor the fluid pressure on the downstream side **124** of the valve **120**. The first pressure sensor **140** monitors the fluid pressure on the upstream side **122** of the valve **120** during calibration for either fluid path **152**, **154**. The following exemplary calibration procedure will focus on calibration of the valve **120** for the fluid path **152** using the second pressure sensor **142** for monitoring fluid pressure on the downstream side **124**. The procedure can also be carried out for calibration of the valve **120** for the fluid path **154** using the third pressure sensor **144** for monitoring fluid pressure on the downstream side **124**.

When the fluid pressures on the upstream side **122** and the downstream side **124** of the valve **120** (monitored by pressure sensors **140** and **142**, respectively) are known, then the flow through the valve **120** can be calculated for a known orifice size of the valve **120**. Additionally, if the hydraulic circuit on the downstream side **124** of the valve **120** is stalled (i.e., no path for fluid to flow, and no potential for volume change), then the additional fluid volume transferred through the valve **120** can be calculated using the following fluid compressibility equation:

$$V_{additional} = \frac{P * V_{initial}}{BulkModulus} \tag{1}$$

where P is the fluid pressure increase on the downstream side **124** of the valve **120**, $V_{initial}$ is the initial fluid volume on the downstream side **124** of the valve **120**, BulkModulus is a measure of the resistance of the fluid to compression, and $V_{additional}$ is the additional fluid volume transferred through the valve. If observed over a period of time, this fluid volume transfer represents a flow rate as:

$$\frac{V_{additional}}{\text{time}} = \frac{P}{\text{time}} * \frac{V_{initial}}{BulkModulus} = Q \tag{2}$$

where Q is the mass flow through the valve **120**.

Mass flow Q can also be calculated using the following orifice equation:

$$Q = CD * A * \sqrt{2 * \frac{\Delta P}{\rho}} \tag{3}$$

where CD is the discharge coefficient, A is the area of the orifice through the valve **120**, ΔP is the pressure difference between the upstream and downstream sides of the valve **120**, and ρ is the fluid density.

Setting mass flow equations (2) and (3) equal and rearranging terms provides:

$$\frac{P}{\text{time}} = \frac{BulkModulus * CD * A * \sqrt{2 * \frac{\Delta P}{\rho}}}{V_{initial}} \tag{4}$$

which relates the fluid pressure increase on the downstream side **124** of the valve **120** to the orifice area of the valve **120**. Thus, an orifice size for the valve **120** can be calculated by monitoring the downstream pressure change. Finding a cracking area of the valve **120** enables a determination of the start of flow point if the rest of the valve characteristic is understood.

FIG. **2** illustrates an exemplary electrohydraulic valve calibration method **200** which will be described with reference to the exemplary hydraulic circuit of FIG. **1**.

At block **202**, calibration preconditions are set which can include, for example, setting a desired performance mode, engine speed, engaging a parking brake of a vehicle, checking hydraulic fluid temperature, etc. At block **204**, the hydraulic pressure is set to an initial pressure, for example 20,000 kilopascals (kPa).

At block **206**, the hydraulic valve **120** is opened and the hydraulic actuator **130** is stalled so that there is no path for fluid to flow, and no potential for volume change on the downstream side **124** of the valve **120**. At block **208**, the hydraulic valve **120** is opened and the pressure on both the upstream side **122** and the downstream side **124** of the hydraulic valve **120** are equalized at the initial equalization pressure. Depending on how long the operator holds the lever to stall the hydraulic actuator **130**, the pressure equalization of block **208** can be accomplished in block **206**, effectively combining blocks **206** and **208** to open the hydraulic valve **120** long enough to stall the hydraulic actuator **130** and equalize the pressures on the upstream and downstream sides **122**, **124** of the hydraulic valve **120**.

At block **210**, the valve **120** is closed with substantially the same equalization pressure on both the upstream side **122** and the downstream side **124** of the hydraulic valve **120**. At block **212**, with the valve **120** closed, the pressure on the upstream side **122** of the valve **120** is raised to an increased pressure, for example 30,000 kPa, creating a pressure difference between the upstream side **122** and the downstream side **124** of the hydraulic valve **120**.

Blocks **214-220** perform a coarse calibration to determine a coarse estimate of the valve current that creates a calibration valve orifice area. At block **214**, the valve current is set to an initial coarse current value, for example 250 milliamps (mA). At block **216**, the valve current is applied to the valve for a coarse time duration, for example 500 milliseconds (msec) and the change in pressure on the downstream side **124** of the valve **120** is calculated. The pressure change can be calculated as the difference in the pressure reading of the pressure sensor **142** before and after applying the valve current for the coarse time duration. At block **218**, it is determined whether the pressure change is less than a pressure change threshold, for example 500 kPa. The pressure change threshold is the pressure change associated with the calibration valve orifice area using equation (4). If the pressure change is less than the pressure change threshold, then at block **220** the valve current is incremented by a coarse current step, for example 10 mA, and the coarse calibration continues back at block **216**. If the pressure change is greater than or equal to the pressure change threshold, then the coarse calibration is complete and control goes to block **226**.

At block **226**, the hydraulic valve **120** is closed. Then at block **228**, the pump **110** is activated to bring the pressure on the upstream side **122** of the valve **120** back to the initial fluid pressure. At block **230**, the hydraulic valve **120** is opened and the pressures on both the upstream side **122** and the downstream side **124** of the hydraulic valve **120** are equalized at the initial equalization pressure. At block **232**, the valve **120** is closed with substantially the same equalization pressure on both the upstream side **122** and the downstream side **124** of the hydraulic valve **120**. At block **234**, with the valve **120** closed, the pressure on the upstream side **122** of the valve **120** is raised to the increased pressure creating a pressure difference between the upstream side **122** and the downstream side **124** of the hydraulic valve **120**.

In an alternative embodiment of the valve calibration procedure, blocks **228-234** can be eliminated. In this alternative embodiment, the finer calibration procedure is started at block **236** right after the coarse calibration is completed at block **218**.

Blocks **236-242** perform a finer calibration to determine a finer estimate of the valve current that creates the calibration valve orifice area. At block **236**, the valve current is set to an initial fine current value. The initial fine current value can be a function of the final valve current determined in the coarse calibration, for example the initial fine current value can be the final valve current determined in the coarse calibration minus the coarse current step. At block **238**, the valve current is applied to the valve for a finer time duration and the change in pressure on the downstream side **124** of the valve **120** is calculated. The finer time duration can be equal to the coarse time duration. The pressure change can be calculated as the difference in the pressure reading of the pressure sensor **142** before and after applying the valve current for the finer time duration. At block **240**, it is determined whether the pressure change is less than the pressure change threshold. If the pressure change is less than the pressure change threshold, then at block **242** the valve current is incremented by a finer current step, for example 1 mA, and the finer calibration continues back at block **238**. If the pressure change is greater than or equal to the pressure change threshold, then the finer calibration is complete and control goes to block **250**.

At block **250**, the valve current control characteristic curve or table relating valve current to valve orifice size over the metering range (between the cracking current and the saturation current) is offset by the difference between the valve current in the supplier valve current control characteristic for the calibration valve orifice area and the valve current at the completion of the finer calibration for the calibration valve orifice area.

The exemplary method of FIG. **2** illustrates two calibration procedures, a coarse calibration procedure followed by a finer calibration procedure. The method could use any number of calibration procedures. For example, one calibration procedure can be performed at a desired calibration resolution or step, or multiple calibration procedures can be performed at finer and finer calibration resolutions or steps.

The calibration procedure does not usually stop at the first detected pressure rise (see, for example blocks **216**, **238**) which would be the cracking current for the valve. The calibration procedure usually proceeds several steps into the metering range of the valve to the calibration valve orifice area that provides a calculated pressure rise on the downstream side of the valve given the time duration the valve current is applied and the pressure difference between the upstream and downstream sides of the valve. The pressure rises on the downstream side of the valve after exceeding the cracking current for the valve can be taken into account when computing the pressure difference on the downstream side of the valve over the time duration. The initial current value and the step duration can be selected to maintain a pressure difference between the upstream side and the downstream side of the electrohydraulic valve during the entire calibration process through when the calculated step orifice size is greater than or equal to the calibration orifice size.

While the disclosure has been illustrated and described in detail in the drawings and foregoing description, such illustration and description is to be considered as exemplary and not restrictive in character, it being understood that illustrative embodiment(s) have been shown and described and that all changes and modifications that come within the spirit of the disclosure are desired to be protected. It will be noted that alternative embodiments of the present disclosure may not include all of the features described yet still benefit from at least some of the advantages of such features. Those of ordinary skill in the art may readily devise their own implementations that incorporate one or more of the features of the present disclosure and fall within the spirit and scope of the present invention as defined by the appended claims.

I claim:

1. A calibration method for an electrohydraulic valve in an electrohydraulic system including a pump and a hydraulic actuator, the electrohydraulic valve having an upstream side between the pump and the electrohydraulic valve and a downstream side on the opposite side of the electrohydraulic valve from the pump between the hydraulic actuator and the electrohydraulic valve, a valve control current controlling an orifice size through the electrohydraulic valve connecting the upstream side with the downstream side, the calibration method comprising:

opening the electrohydraulic valve;

stalling the hydraulic actuator to prevent volume changes in the electrohydraulic system during calibration;

closing the electrohydraulic valve with the upstream and downstream sides of the electrohydraulic valve substantially equalized at an equalization pressure;

increasing pressure on the upstream side of the electrohydraulic valve to an increased pressure using the pump, the increased pressure being greater than the equalization pressure on the downstream side of the valve; and

finding a calibration valve control current that provides a calibration orifice size through the electrohydraulic valve by monitoring pressure on the downstream side of the electrohydraulic valve.

2. The calibration method of claim **1**, wherein finding a calibration valve control current comprises:

initializing a step current to an initial current value, the electrohydraulic valve being closed when the valve control current equals the initial current value;

setting the valve control current for the electrohydraulic valve to the step current for a step duration;

sensing pressure on the downstream side of the electrohydraulic valve after setting the valve control current to the step current for the step duration;

calculating a step orifice size through the electrohydraulic valve based on the sensed pressure on the downstream side of the electrohydraulic valve; and

if the calculated step orifice size is less than the calibration orifice size, increasing the step current by a current increment and repeating the setting, sensing and calculating steps for the increased step current;

if the calculated step orifice size is greater than or equal to the calibration orifice size, using the step current as the calibration valve control current.

3. The calibration method of claim **2**, wherein calculating a step orifice size based on the sensed pressure on the downstream side of the electrohydraulic valve comprises:

determining a flow rate through the electrohydraulic valve based on the difference in sensed pressure on the downstream side of the electrohydraulic valve before and after setting the valve control current to the step current for the step duration; and

determining the step orifice size of the electrohydraulic valve for the step current using the determined flow rate through the electrohydraulic valve and the compressibility of the fluid in the electrohydraulic system.

4. The calibration method of claim **3**, wherein the electrohydraulic valve has a valve current control characteristic relating the valve control current to the orifice size through the electrohydraulic valve; and the calibration method further comprising:

calculating a table offset for the valve current control characteristic based on the calibration valve control current that provides the calibration orifice size.

5. The calibration method of claim **4**, wherein calculating a table offset for the valve current control characteristic comprises:

using the valve current control characteristic to determine a table current entry for the valve control current that provides the calibration orifice size; and

computing the table offset as the difference between the table current entry and the calibration valve control current.

6. The calibration method of claim **4**, wherein the calibration orifice size is selected to reduce manufacturing tolerance impacts on the calibration method.

7. The calibration method of claim **3**, wherein the flow rate through the electrohydraulic valve is greater than zero for at least one step current before increasing the step current to the calibration valve control current.

8. The calibration method of claim **3**, further comprising:

selecting the initial current value and the step duration to maintain a pressure difference between the upstream side and the downstream side of the electrohydraulic valve when the calculated step orifice size is greater than or equal to the calibration orifice size.

9. The calibration method of claim **1**, wherein finding a calibration valve control current comprises:

performing a coarse calibration starting at an initial coarse current value and using a coarse current increment to find a coarse control current estimate; and

performing a finer calibration starting at an initial finer current value and using a finer current increment to find the control current estimate; the initial finer current value being selected based on the coarse control current estimate, and the finer current increment being less than the coarse current increment.

10. The calibration method of claim **9**, wherein the electrohydraulic valve is closed when the valve control current equals the initial coarse current value, and performing a coarse calibration comprises:

initializing the valve control current to the initial coarse current value;

applying the valve control current to the electrohydraulic valve for a coarse step duration;

sensing pressure on the downstream side of the electrohydraulic valve after applying the valve control current for the coarse step duration;

calculating a step orifice size through the electrohydraulic valve based on the sensed pressure on the downstream side of the electrohydraulic valve;

if the calculated step orifice size is less than the calibration orifice size, increasing the valve control current by the coarse current increment and repeating the applying, sensing and calculating steps of the coarse calibration for the increased valve control current;

if the calculated step orifice size is greater than or equal to the calibration orifice size, setting the coarse control current estimate to the valve control current; and

wherein performing a finer calibration comprises:

initializing the valve control current to the coarse control current estimate minus a current offset;

applying the valve control current to the electrohydraulic valve for a finer step duration;

sensing pressure on the downstream side of the electrohydraulic valve after applying the valve control current for the finer step duration;

calculating the step orifice size through the electrohydraulic valve based on the sensed pressure on the downstream side of the electrohydraulic valve;

if the calculated step orifice size is less than the calibration orifice size, increasing the valve control current by the finer current increment and repeating the applying, sensing and calculating steps of the finer calibration for the increased valve control current;

if the calculated step orifice size is greater than or equal to the calibration orifice size, setting the control current estimate to the valve control current.

11. The calibration method of claim **10**, wherein the coarse current increment is at least double the finer current increment.

12. The calibration method of claim **9**, further comprising, after performing the coarse current calibration and before performing the finer current calibration:

equalizing pressures on the upstream side and the downstream side of the electrohydraulic valve at the equalization pressure;

closing the electrohydraulic valve with the upstream and downstream sides of the electrohydraulic valve substantially equalized at the equalization pressure; and

increasing pressure on the upstream side of the electrohydraulic valve to the increased pressure using the pump.

13. The calibration method of claim **1**, wherein the pump has an electronically controlled displacement.

14. An electrohydraulic valve calibration system comprising:

an electrohydraulic valve having a variable size orifice, the orifice size through the electrohydraulic valve being controlled by a valve control current; the electrohydraulic valve has an upstream side on one side of the electrohydraulic valve and a downstream side on the opposite side of the electrohydraulic valve; and fluid flows through the variable size orifice between the upstream side and the downstream side of the electrohydraulic valve;

a pump on the upstream side of the electrohydraulic valve;

a hydraulic actuator on the downstream side of the electrohydraulic valve, where the pump pumps a fluid from the upstream side through the electrohydraulic valve to the downstream side;

an upstream pressure sensor for sensing an upstream fluid pressure on the upstream side of the electrohydraulic valve between the electrohydraulic valve and the pump;

a downstream pressure sensor for sensing a downstream fluid pressure on the downstream side of the electrohydraulic valve between the electrohydraulic valve and the hydraulic actuator; and

a controller;

wherein the controller opens the electrohydraulic valve, stalls the hydraulic actuator and then closes the electrohydraulic valve with the upstream and downstream fluid pressures at an equalization pressure; the controller then activates the pump to increase the upstream fluid pressure to an increased pressure, and then finds a calibration valve control current that provides a calibration orifice size through the electrohydraulic valve by monitoring the downstream fluid pressure.

15. The electrohydraulic valve calibration system of claim **14**, wherein the controller sequentially steps through a series of increasing valve control currents until the calibration valve control current is determined; at each step in the series of increasing valve control currents, the controller receives a signal from the downstream pressure sensor that indicates the downstream fluid pressure and calculates a step orifice size through the electrohydraulic valve based on the sensed downstream fluid pressure; and the controller determines the calibration valve control current based on the valve control current of the step where the calculated step orifice size is greater than or equal to the calibration orifice size.

16. The electrohydraulic valve calibration system of claim **15**, wherein the controller calculates a flow rate through the electrohydraulic valve based on a change in the sensed downstream fluid pressure before and after each step in the series of increasing valve control currents, and calculates the step orifice size using the calculated flow rate through the electrohydraulic valve and a compressibility of the fluid.

17. The electrohydraulic valve calibration system of claim **16**, further comprising a valve current control characteristic for the electrohydraulic valve, the valve current control characteristic relating the valve control current to the orifice size through the electrohydraulic valve; and wherein the controller calculates a current offset for the valve current control characteristic based on the calibration valve control current and the calibration orifice size.

18. The electrohydraulic valve calibration system of claim **17**, wherein the current offset is the difference between a table current entry in the valve current control characteristic for the valve control current that provides the calibration orifice size and the calibration valve control current.

19. The electrohydraulic valve calibration system of claim **14**, wherein the controller starts at an initial coarse valve control current and sequentially steps through a series of increasing valve control currents at a coarse current increment until a coarse valve control current estimate is determined, and then starts at an initial finer valve control current and sequentially steps through a series of increasing valve control currents at a finer current increment until the calibration valve control current estimate is determined, the finer current increment being less than the coarse current increment, and the initial finer valve control current being determined based on the coarse valve control current estimate;

wherein at each step in the series of increasing valve control currents, the controller receives a signal from the downstream pressure sensor that indicates the downstream fluid pressure and calculates a step orifice size through the electrohydraulic valve based on the sensed downstream fluid pressure, and the controller stops the sequential steps when the calculated step orifice size is greater than or equal to the calibration orifice size.

20. The calibration system of claim **14**, wherein the pump has an electronically controlled displacement.

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